TITLE OF THE INVENTION

WIRELESS COMMUNICATIONS SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to wireless communications systems and, more specifically, to a system for data communications among plurality of terminals connected to one another through a wireless network, and a method used therein for scheduling (method for assigning a transmission band for data transmission for each communications link), dividing a data packet, and carrying out re-transmission when an error occurs.

Description of the Background Art

There have been various systems for data communications among personal computers (hereinafter, PCs) or between PCs and a host computer connected to one another through a network. A wired network such as Ethernet of IEEE 802.3 and Token-Ring of IEEE 802.5 have been part of the mainstream of such network. With the advent of portable PC terminals without requiring any wiring, however, such wired network is gradually shifting to a wireless network.

The CMSA (Carrier Sense Multiple Access) method, which is one of the conventional access techniques using a wireless network is now briefly described with reference to FIG. 21.

In FIG. 21, PCs 501 to 504 are connected to wireless access devices 505 to 508, respectively. The wireless access devices 505 to 508 are connected to one another through a wireless network. Here, described is a case where data is transmitted from the PC 501 to the PC 502, and then, after a short while, another data is transmitted from the PC 503 to PC 504.

When receiving a data transmission request from the PC 501, the wireless access device 505 measures received field intensity through a receiving operation to check whether any other wireless access device is in communication or not. If not, the wireless access device 505 sequentially transmits the data provided by the PC 501 to the wireless access device 506. The wireless access device 506 transfers the data received from the wireless access device 505 to the PC 502.

When receiving a data transmission request from the PC 503 shortly after the wireless device 505 receives the request from the PC 501, the wireless access device 507 similarly measures received field intensity through the receiving operation to check whether any other wireless access device is in communication or not. At this time, the wireless access device 505 is still carrying out data transmission. Therefore, the wireless access device 507 waits until this data transmission ends. Then, after this data transmission ends, the wireless access device 507 sequentially transmits the data provided by the PC 503 to the wireless access device 508. The wireless access device 508

transfers the data received from the wireless access device 507 to the PC 504.

However, in conventional wireless communications systems using the CSMA method, if the plurality of PCs each send a transmission request simultaneously, the wireless access devices try to start transmission, leading to transmission collisions on the wireless network. This is because the wireless access devices can only check transmission actually being made at the time of measuring field intensity. In other words, the wireless access devices cannot detect transmission that will be made in future. Moreover, the wireless access devices are not capable of detecting collision, and therefore may erroneously determine that transmission has succeeded even though not succeeded due to collision. Such collision will occur more frequently as the number of wireless access devices or the number of transmissions tried by the wireless access devices increases.

To get around the above problem, time-division transmission methods such as TDM and TDMA can be applied so as to avoid transmission collisions on the wireless network when a plurality of wireless access devices each send a data transmission request simultaneously. In such time-division methods, a transmission band is previously divided into several, and divided band is assigned for each data transmission request. Thus, each wireless access device can make data transmission using each specific transmission band, and transmission collisions can be prevented

on the wireless network.

In near future, a network such as LAN will be introduced to households. For such household network, a wireless network is desirable because wiring is not required and devices connected to the network can be easily moved. In such network, digital video data will be mostly used as transmission contents. However, such digital video data is generally large in volume, and requires high speed for transmission. Moreover, for transmission of digital video data from a set-top box or video player to a television set, real-time transmission is required.

In the above-described conventional wireless communications system using the CSMA method, however, transmission efficiency is low because transmission collisions on the wireless network should be avoided. Therefore, it is difficult to achieve real-time, high-capacity, high-speed transmission of digital video data.

Furthermore, in the conventional time-division wireless communications system, a transmission band is fixedly assigned to each generated data transmission request. Therefore, when a state of data transmission is changed, the transmission band cannot be changed until the data transmission ends. One example of wireless communications systems where a transmission band is fixedly assigned is disclosed in Japanese Patent Laid-Open Publication No. 11-252663 (1999-252663). Therefore, in the conventional wireless communications system, real-time data

transmission may be impaired.

SUMMARY OF THE INVENTION

Therefore, an object of the present invention is to provide a wireless communications system in which real-time data typified by moving-picture data and burst data typified by control data can be both transmitted, and a transmission band can be dynamically assigned according to a state of data transmission.

The present invention has the following features to achieve the object above.

The present invention is directed to a wireless communications system in which a wireless access unit (hereinafter, master station) for managing a wireless network and one or more other wireless access units (hereinafter, slave stations) are on the wireless network, and data of one or a combination of communication types including:

CBR (constant in transmission speed and data period);

VBR (variable in transmission speed and constant in data period);

ABR (constant in transmission speed and variable in data period); and

UBR (variable in transmission speed and data period) is transmitted between the master station and one of the slave stations or between the slave stations,

the master station comprising a scheduler for regularly

determining (scheduling) transmission band assignment including information about transmission timing of the data, a transmission amount, and the master station or any of the slave stations that is allowed to access,

in order to make a request for setting a communication link for data transmission, the master station providing said scheduler with a communication parameter for the data transmission,

in order to make the request for setting the communication link for data transmission, the slave station providing the scheduler with a communication parameter for the data transmission by transmitting a communication parameter for the data transmission to the master station by using a request packet,

the master station giving the transmission band assignment scheduled by the scheduler to the slave station by using a band assignment packet, and recognizing the transmission band assignment, and

a transmitting station (the master station or the slave station that sends the data) and a receiving station (the master station or the slave station that receives the data) between which the communication link is set by the transmission band assignment carrying out bidirectional data transmission according to the transmission band assignment.

Here, preferably,

when the communication type indicated by the communication

parameter is CBR, VBR, or ABR, the scheduler rejects the request for setting the communication link if a transmission bandwidth required for the communication link exceeds an unused transmission bandwidth (empty bandwidth), and receives the request for setting the communication link and updates a sum of transmission bandwidths in use for already-allocated communication links (used bandwidth) if otherwise,

when the communication type indicated by the communication parameter is UBR, the scheduler receives the request for setting the communication link irrespectively of the empty bandwidth.

Also, preferably, the scheduler

recognizes a state of data receiving for each communication link by receiving, from the receiving station, an acknowledgement packet indicating the state of data receiving as to the bidirectional data transmission in which the communication link is set, and

determines the transmission band assignment so as to reflect the state of data receiving and satisfy the previously-set communication parameters.

Also, preferably, for setting the communication link,

if the communication type is CBR, the scheduler multiplies a speed parameter indicating a transmission speed by a period parameter indicating a data occurrence period to calculate a data amount parameter indicating an amount of data to be transmitted,

if the communication type is VBR, the scheduler divides

the data amount parameter by the period parameter to calculate the speed parameter, and

if the communication type is ABR, the scheduler divides the data amount parameter by the speed parameter to calculate the period parameter.

Also, preferably,

when the communication type indicated by the communication parameter is CBR, VBR, or ABR,

the scheduler calculates a difference Tb between a present time or a reference time, which is a transmission time of the assigned transmission band, and a time when data transmission on each communication link has been completed,

when the difference Tb is positive, for each communication link, the scheduler

calculates a difference Vdd between a data amount parameter included in the communication parameter and indicating an amount of data to be transmitted and an amount of data already received by the receiving station (received data amount),

calculates a priority value by subtracting an overhead bandwidth from an entire transmission bandwidth of the system to obtain an effective transmission bandwidth, multiplying the effective transmission bandwidth by the difference Tb to obtain a value, then dividing the difference Vdd by the value, and

selects one or more communication links whose priority value is not less than a predetermined value and predetermined

in decreasing order or whose priority value is not less than a random number generated within a predetermined range as the communication link assigned the transmission band, and

when the difference Tb is not more than 0, the scheduler selects one or more communication links in increasing order of the difference Tb as the communication link assigned the transmission band.

Also, preferably, the scheduler updates the received data amount of each communication link based on an acknowledgement packet indicating a state of data receiving transmitted from the receiving station.

Also, preferably, the scheduler updates the received data amount of each communication link by using the transmission amount determined by the transmission band assignment, and corrects the received data amount to an effective value based on an acknowledgement packet indicating a state of data receiving transmitted from the receiving station.

Also, preferably, when the difference Vdd of the communication link for scheduling is negative, the scheduler carries out any one of operations of deleting a setting of the communication link, resetting the communication link by the communication parameters currently used, and resetting the communication link with the communication type changed to UBR.

Also, preferably, when the communication type indicated by the communication parameter is UBR, the scheduler carries out the

transmission band assignment according to an order in which the communication link has been set (requested) or a priority order of the priority parameter included in the communication parameter.

Also, preferably, when a period parameter indicating a data period is further provided, the scheduler calculates a difference Tb between a present time or a reference time, which is a transmission time of the assigned transmission band, and a time when data transmission on each communication link has been completed, and carries out transmission band assignment only when the difference Tb is not more than 0.

Also, preferably, when a data amount parameter indicating an amount of data to be transmitted is provided, if an amount of data already received by the receiving station (received data amount) exceeds the data amount parameter, the scheduler deletes setting of a relevant communication link.

Also, preferably, when detecting that the transmission band of the set communication link is not used, the scheduler deletes setting of the communication link.

As such, in the present invention, scheduling results of the scheduler, that is, transmission band assignment results are regularly transmitted to the slave station by using a band assignment packet, and bidirectional data transmission is made using the assigned transmission band. Thus, for any data of CBR, VBR, ABR, and UBR, a band required for data transmission is

allocated in advance, and data transmission can be completed by a required end time. Moreover, communication links whose priority is not less than the random number are subjected to scheduling, thereby reducing load on the scheduler.

Furthermore, preferably, when assigning data packet transmission from the transmitting station to each transmission band with the communication link set therein a predetermined number of times, the scheduler assigns transmission of the acknowledgement packet from the receiving station at least once.

Thus, one transmission band is used for data packet transmission and acknowledgement packet transmission. Therefore, the transmission band can be used effectively.

Still further, preferably, the scheduler carries out transmission band assignment by dynamically changing a data packet based on communication quality of a wireless channel so that a packet length is shortened when more communication errors occur, and lengthen when fewer.

Thus, for the communication link with more errors, a wider transmission band can be used for data transmission.

Still further, preferably, the master station gives, to the slave station, the band assignment packet with a probability parameter for access control of the request packet added thereto, and

the slave station transmits the request packet only when the given probability parameter exceeds a random number generated

within a range of values that the probability parameter can take.

Thus, access concentration on the same transmission band can be avoided.

Still further, preferably, when transmission band assignment for data transmission has been carried out by the scheduling, the transmitting station divides the data into a specified length for generating data packets for transmission.

Still further, preferably, when a plurality of communication links are set to the transmitting station, if there is no data packet to be transmitted on a specific communication link, the transmitting station transmits a data packet to be transmitted on another communication link by using a transmission band assigned to the specific communication link.

Thus, a transmission band not in use can be effectively used.

Still further, preferably, the transmitting station transmits the request packet by using a transmission band in which a communication link is set.

Thus, the request packet is transmitted by using the transmission band in which a communication link has been already set for the transmitting station, thereby avoiding a conflict with other stations.

Still further, preferably, the master station transmits, to the slave station, the band assignment packet with a transmission time stamp value indicating a transmission time

added thereto, and

the slave station synchronizes a time counter thereof with a time counter of the master station by using the transmission time stamp value.

Thus, the slave station can correctly carry out data transmission according to an instruction by the band assignment packet from the master station.

Still further, preferably, the slave station transmits, to the master station, the request packet with a transmission time stamp value indicating a transmission time added thereto,

when receiving the request packet with the transmission time stamp value added thereto, the master station calculates a space propagation delay time from a difference between a receive time and the transmission time stamp value, and gives, to the slave station, the band assignment packet including an adjusted value according to the space propagation delay time, and

the slave station corrects transmission timings of the request packet and the data packet according to the given adjusted value.

Thus, a wasted transmission band due to space propagation delay can be prevented. Therefore, the transmission band can be effectively used.

Still further, preferably, the receiving station indicated by a destination address of the band assignment packet

when receiving the band assignment packet correctly,

carries out intermittent receiving in timing when the data packet transmitted from the transmitting station and the band assignment packet next transmitted from the master station are received, and

when not receiving the band assignment packet correctly, carries out intermittent receiving only after receiving the band assignment packet next correctly.

Thus, power consumption at the receiving station can be reduced.

These and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram showing one example of environment where a wireless communications system according to one embodiment of the present invention is used;

FIG. 2 is a block diagram showing one example of structure of a master station 10;

FIG. 3 is a block diagram showing one example of structure of a slave station 20;

FIG. 4 is a diagram showing one example of structure of a band assignment packet;

FIGS. 5A and 5B are diagrams each showing a relation between the band assignment packet and assigned transmission band;

FIG. 6 is a diagram showing one example of structure of a request packet;

FIG. 7 is a flow chart showing a time synchronization process carried out by the slave station 20;

FIG. 8 is a flow chart showing a fine adjustment process for transmission timing carried out by the master station 10;

FIG. 9 is a flow chart showing a transmission band assignment process carried out by the master station 10;

FIGS. 10 and 11 are flow charts each showing scheduling of CBR/VBR/ABR data of FIG. 9 in detail;

FIG. 12 is a flow chart showing scheduling of UBR data of FIG. 9 in detail;

FIG. 13 is a diagram showing one example of structure of a data packet;

FIG. 14 is a diagram showing one example of structure of an acknowledgement packet;

FIG. 15 is a flow chart showing a process carried out by the master station 10 as a transmitting station;

FIG. 16 is a flow chart showing a process carried out by the master station 10 as a receiving station;

FIG. 17 is a flow chart showing a process carried out by the slave station 20 as the transmitting station;

FIG. 18 is a flow chart showing a process carried out by the slave station 20 as the receiving station;

FIGS. 19 and 20 are block diagrams each showing one example

of structure of the wireless communications system according to one embodiment to the present invention; and

FIG. 21 is a block diagram showing one example of structure of the conventional wireless communications system.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 is a diagram showing one example of environment where a wireless communications system according to one embodiment of the present invention is used. As shown in FIG. 1, in the wireless communications system according to the embodiment of the present invention, data transmission is made among devices such as PCs and television receivers and networks (hereinafter collectively referred to as terminals). Such data transmission includes transmission of video images and video signals to a television and access to the Internet. In the wireless communications system, optimal data transmission is made by effectively using limited communications resources. In the wireless communications system according to the present embodiment, a plurality of wireless access units 2 connected to respective terminals are provided, and wirelessly connected to one another to form a network 1.

In the present invention, any one of the wireless access units 2 manages total data communications taking place in the wireless communications system. In the following description, the one that manages total data communications is denoted as a master station 10, while the others as slave stations 20.

First, the master station 10 and the slave stations 20 are each briefly described. FIG. 2 is a block diagram showing one example of structure of the master station 10. FIG. 3 is a block diagram showing one example of structure of the slave station 20.

In FIG. 2, the master station 10 includes an interface 11, a controller 12, a packet transmitter 13, a packet receiver 14, and a scheduler 15. The interface 11 connects the terminals and the master station 10 together. The controller 12 transmits and receives a predetermined packet and controls operation of the scheduler 15 in order to achieve optimal data transmission in the wireless communications system. The packet transmitter 13 wirelessly transmits the packet provided by the controller 12 to the slave stations 20. The packet receiver 14 receives a packet wirelessly transmitted from the slave station 20 for output to the controller 12. The scheduler 15 determines assignment of transmission band (timing of packet transmission, amount of data transmission, and the like) to allocate a communication link required for data transmission. This scheduler 15 can handle data of the following communication types: CBR (Constant Bit Rate) at constant transmission speed and constant period of data occurrence (hereinafter, data period), as would be appropriate for voice; VBR (Variable Bit Rate) at variable transmission speed and constant data period, as would be appropriate for MPEG2 video; ABR (Available Bit Rate) at constant transmission speed and variable data period, as would be appropriate for file data

transfer; and UBR (Unspecified Bit Rate) at variable transmission speed and variable data period, as would be appropriate for control data.

In FIG. 3, the slave station 20 includes an interface 20, a controller 22, a packet transmitter 23, and a packet receiver 24. The interface 21 connects the terminal and the slave station 20 together. The controller 22 transmits and receives a predetermined packet in order to achieve optimal data transmission in the wireless communications system based on the management by the master station 10. The packet transmitter 23 wirelessly transmits the packet provided by the controller 22 to the master station 10 or any of the other slave stations 20. The packet receiver 24 receives the packet wirelessly transmitted from the master station 10 or any of the other slave stations 20 for output to the controller 22.

Next, the operation carried out between the master station 10 and each slave station 20 in the wireless communications system according to the embodiment of the present invention is specifically described in sequence.

(1) Notification of a state of transmission band assignment from the master station 10 to each salve station 20

First, the master station 10 divides, in advance, the entire transmission band usable in the wireless communications system into several in time. The master station 10 notifies each slave station 20 of a state of each transmission band assignment

(whether new assignment request has been received or how transmission band has been assigned) at regular or irregular time intervals. For this notification, a band assignment packet (hereinafter, Map_Packet) is used, which is shown in FIG. 4. As shown in FIG. 4, Map_Packet is composed of a header portion, a plurality of band information portions that correspond to the time-divided transmission bands, and an ender portion.

The header portion is comprised of a transmission time stamp, sender address, destination address, packet type, map number, and data length. In the transmission time stamp, a time when Map_Packet is transmitted is stored based on a time counter of the master station 10. In the sender address, the address of the master station 10, which sends Map_Packet, is stored. In the destination address, a broadcast address indicating all slave stations 20 is stored. With the broadcast address stored, the entire transmission band can be used as a competing access band for which the slave stations 20 will compete to transmit data. In the packet type, information indicating that this packet is Map_Packet is stored. In the map number, a serial number provided to the packet is stored. Note that the one first transmitted (after system startup, for example) is provided with number one. In the data length, the data length of all band information portions is stored.

The plurality of band information portions each represent how the transmission band is assigned. Each band information

portion is composed of transmission time, transmission amount, communication link number, sender address, and destination address. In the transmission time, a start time of the time-divided transmission band is stored. In the transmission amount, the amount of data that can be transmitted from the start time is stored. In the communication link number, a number for identifying a communication link is stored. In the sender address, the address of the slave station 20 or the master station 10 that uses the communication link for data transmission is stored. In the destination address, the address of the slave station 20 or the master station which receives data by using the communication link is stored. Here, the transmission amount, sender address, and destination address are information to be used when the communication link is established, which will be described later. Therefore, they are blank if the transmission band is not yet in use. Note that, to indicate that the transmission band is not in use, the communication link number is set to 0, for example.

The ender portion is composed of information for use in well-known packet error detection.

This Map_Packet is generated based on scheduling (will be described later) executed by the scheduler 15 every time a notification is made. Therefore, Map_Packet always makes an instruction about the optimal state of communications at the time of generation. The generated Map_Packet is provided to each slave station 20.

A relation between this Map_Packet and the transmission band is shown in FIGS. 5A and 5B. As shown in FIG. 5A, Map_Packet indicates how transmission bands that follow Map_Packet are assigned. Various packets hereinafter described are transmitted with the use of the transmission band assigned by Map_Packet. Also, as shown in FIG. 5B, if Map_Packet is for a transmission band that comes not immediately thereafter but after a short while, pipeline processing can be performed. Thus, it is possible to reduce possible waiting time when it takes much time to carry out a transmission/receiving process, which improves efficiency.

Note that, either or both of a modulation scheme and error correction scheme used in Map_Packet transmission may be highly error proof so as to achieve reliable transmission of Map_Packet to each slave station 20. Thus, access to the master station 10 from each slave station 20 can be ensured.

(2) Sending a transmission band assignment request from the slave station 20 to the master station 10

Next, the operation of the slave station 20 when it receives a new data transmission request from the terminal connected thereto is described.

In this case, the slave station 20 analyzes information related to data that is newly requested for transmission (hereinafter, requested data) through the interface 21. With this analysis, the slave station 20 obtains information about the communication type, communication parameters (transmission

amount, transmission speed, data period, and priority), and destination of the requested data. Then, the slave station 20 transmits, to the master station 10, a request for assigning a transmission band for data transmission (allocating a communication link) together with the obtained information. For this request, a request packet (Request_Packet) shown in FIG. 6 is used. As shown in FIG. 6, Request_Packet is composed of a transmission time stamp, sender address, destination address, packet type, communication type, communication link number, speed parameter, period parameter, data amount parameter, priority parameter, and error detection.

In the transmission time stamp, a time when Request_Packet is transmitted is stored based on a time counter of the slave station 20. In the sender address, the address of the slave station 20 that transmits Request_Packet is stored. In the destination address, the address of the master station 10 is stored. In the packet type, information indicating that this packet is Request_Packet is stored. In the communication type, any one of the above-described CBR, VBR, ABR, and UBR is stored according to the requested data. Stored in the communication link number is a number provided to a communication link when the communication link is allocated, the number that the slave station 20 desires to use for identifying data transmission. By varying the communication link number, one slave station 20 can have a plurality of communication links at a time. In the speed

parameter, information indicating a transmission speed of the requested data is stored. In the period parameter, information indicating a period of data occurrence in the requested data is stored. In the data amount parameter, information indicating the transmission amount of the requested data is stored. In the priority parameter, information about a level of priority that the requested data deserves for transmission band assignment is stored. Note that the priority parameter is not necessarily required.

After generating Request_Packet for the requested data, the slave station 20 refers to Map_Packet received from the master station 10, and transmits Request_Packet to the master station 10 by using a transmission band to which a new assignment request is directed (unused transmission band). More specifically, the slave station 20 finds any band information portion whose communication link number indicates that the band is not in use (0, in the above example). Then, the slave station 20 transmits Request_Packet to the master station 10 at the transmission time of the found band information portion (arbitrary one if two or more band information portions are found).

Note that, if the master station 10 itself newly receives a data transmission request from the terminal connected thereto, transmission and receiving of Request_Packet is not carried out.

In an initial state, each slave station 20 is not synchronized in time with the master station 10. Therefore, to

transmit Request_Packet at the transmission time indicated by Map_Packet, the slave station 20 has to be synchronized in time with the master station 10. Here, time synchronization means that the time counter included in the controller 22 of the slave station 20 is synchronized with the time counter included in the controller 12 of the master station 10.

Hereinafter, synchronization between both time counters is specifically described with reference to FIG. 7.

When receiving Map_Packet from the master station 10 without error (steps S702, S703), the packet receiver 24 of each slave station 20 outputs Map_Packet together with a time stamp indicating a receive time (hereinafter, receive time stamp) to the controller 22. The controller 22 calculates a time difference between the transmission time stamp provided to Map_Packet and the receive time stamp, and then adds thereto a fixed process delay time due to modulation/demodulation and the like involved in data transmission for calculating a correction value (step S704). The slave station 20 then corrects its own time counter with the correction value (step S711). This correction value is calculated every time the slave station 20 receives Map_Packet. When the correction value falls within a predetermined range ± K (which is equivalent to allowable space propagation delay time) a predetermined number of times M successively, it is determined that synchronization is established (steps S706 through S709). In an asynchronous state, Request_Packet cannot be transmitted

correctly at the transmission time indicated by Map_Packet. Therefore, transmission of Request_Packet from the slave station 20 is prohibited.

Even after time synchronization is established, the controller 22 calculates the correction value. If the calculated correction value does not fall within the predetermined range ± K, an upper limit +K or a lower limit -K is taken as an effective correction value for actual use (steps S712, S713). For example, assume that K = 40ms. When the calculated correction value is -50ms, -40ms is taken as the effective correction value, and when 60ms, 40ms is taken. Note that the time counter may be managed with the number of reference clocks in the system. The slave station 20 then corrects its own time counter with the effective correction value (step S718). If this effective correction value does not fall within the predetermined range ±K a predetermined number of times P successively, it is determined that asynchronization is established (steps S714 through S716).

With the above process, the master station 10 and each slave station 20 are synchronized in time.

Furthermore, timing of packet transmission may be finely adjusted with packet transmission and receiving after time synchronization. This fine adjustment is done by measuring a variable space propagation delay time and correcting the timing, which improves synchronization accuracy.

How the transmission timing is finely adjusted is now

specifically described below with reference to FIG. 8.

When receiving a packet (Request_Packet, for example) from any slave station 20, the master station 10 outputs the packet together with the receive time stamp indicating a receive time to the controller 12 (step S802). The controller 12 calculates a time difference Td between the transmission time stamps provided to the packet and the receive time stamp (step S803). The values of the time counters of the master station 10 and the slave station 20 originally differ for the space propagation delay time due to the above time synchronization using Map_Packet. Therefore, the time difference Td is equivalent to a space propagation delay time that is taken for a single exchange of data (back-and-forth space propagation delay time). An adjusted value based on this back-and-forth space propagation delay time is added to Map_Packet, for example, and given from the master station 10 to each slave station 20 (step S804). Each slave station 20 corrects packet transmission timing thereafter based on the given adjusted value (step S806).

When the master stations 10 gives the adjusted value, the scheduler 15 thereof deletes a band that can be deleted with the adjusted value (which is equivalent to a time period when any packet is not transmitted) from currently-assigned bands.

As described above, the master station 10 sets the broadcast address as the destination address for Map_Packet. Therefore, two or more slave stations 20 might simultaneously transmit

Request_Packet to the same unused transmission band. Thus, how to avoid such access concentration is now described.

The master station 10 transmits, to each slave station 20, Map_Packet with a predetermined probability parameter Ap added to each band information portion. Note that the communication link number may be replaced by the probability parameter Ap. This probability parameter Ap is a variable for suppressing the number of accesses from the slave stations 20. On the other hand, each slave station 20 generates a random number Cp within a predetermined range of values which the probability parameter Ap can take. The slave station 20 is adapted to be able to transmit Request_Packet only to the transmission band whose probability parameter Ap exceeds the random number Cp (Ap > Cp). For example, if the probability parameter AP is "512", the slave station 20 can transmit Request_Packet when the generated random number Cp is "100", while cannot when "700". Thus, access concentration on one transmission band can be avoided.

Note that receive error of Request_Packet in each transmission band may be measured for adjusting the frequency of access. In this case, the probability parameter Ap is decreased if many errors are found, while increased if few.

(3) Transmission band assignment process by the master station 10

Next, the transmission band assignment process (scheduling) carried out by the master station 10 that receives

Request_Packet from the slave station 20 and that gives Map_Packet at predetermined intervals is described with reference to FIGS. 9 through 12.

When receiving Request_Packet from the slave station 20, the master station 10 carries out scheduling for setting a new communication link based on the received Request_Packet. Also when giving Map_Packet at the predetermined intervals, the master station 10 carries out scheduling for resetting the existing communication link based on a respond packet, which will be described later. Scheduling is carried out by the scheduler 15 according to an instruction from the controller 12. Here, when receiving Request_Packet, the communication parameters provided to the master station 10 varies with the communication type of the requested data. Therefore, the scheduler 15 carries out in advance a process as described below (FIG. 9).

For CBR, a speed parameter S and a period parameter P are provided. Therefore, the scheduler 15 calculates a data amount parameter Vd (= S $\times$ P) from these provided parameters. For example, when S = 6Mbps and P = 33ms, $(6 \times 10^6) \times (33 \times 10^{-3})$ = 198000 bits (24750 bytes).

For VBR, the period parameter P and the data amount parameter Vd are provided. Therefore, the scheduler 15 calculates the speed parameter S (= Vd / P) from these provided parameters. For example, when P = 50ms and Vd = 32000 bits (4000 bytes), $32000 / (50 \times 10^{-3})$ = 640kbps.

For ABR, the speed parameter S and the data amount parameter Vd are provided. Therefore, the scheduler 15 calculates the period parameter P (= Vd / S) from these provided parameters. For example, when S = 3Mbps and Vd = 24000 bits (3000 bytes), 24000 / (3×10^6) = 8ms.

For CBR, VBR, or ABR, the scheduler 15 checks to see if there is any transmission bandwidth not in use (empty bandwidth Be). The scheduler 15 holds a sum of values of the speed parameters S of the already-allocated communication links, which is equivalent to a used bandwidth Bu. Therefore, the empty bandwidth Be can be calculated by subtracting the used bandwidth Bu from an effective transmission bandwidth Br. Here, the effective transmission bandwidth Br is obtained by subtracting an overhead bandwidth Bo from an entire transmission bandwidth Bs of the system. The bandwidth Bo includes loss bands due to overhead involved in packet transmission, packet error, and scheduling error (ideal scheduling cannot be done), and a band reserved for UBR data transmission. Note that the bandwidth Bo may be dynamically changed based on the level of communication quality determined in consideration of transmission error, measured receive field intensity, and the like.

If the empty bandwidth Be is found, the scheduler 15 then determines whether the speed parameter S, which is equivalent to a requested transmission bandwidth Bl, exceeds the empty bandwidth Be. If exceeds, transmission band assignment is

difficult. Therefore, the scheduler 15 rejects a link setting request by Request_Packet from the slave station 20. On the other hand, if not exceed, new transmission band assignment can be made. Therefore, the scheduler 15 receives the setting request and updates the used bandwidth Bu (Bu $\leftarrow$ Bu + Bl).

Note that an upper limit of the bandwidth that can be used for data of CBR, VBR, and ABR may be set. If the used bandwidth Bu exceeds this upper limit, the setting request is rejected. Also in this case, it is required to calculate a time when the data indicated by the data amount parameter Vd should be completely received by a receiving side (completion time Te). The scheduler 15 obtains the completion time Te by adding the period parameter S to the present time. The present time may be a transmission time of the transmission band assigned by scheduling. Also, the scheduler 15 manages received data amount Vdr (initial value = 0) indicating that how much requested data has been received by the receiving side.

On the other hand, for UBR, the scheduler 15 receives the setting request without checking the empty bandwidth Be. For UBR, any communication parameters are normally not provided. In some cases, however, the data amount parameter Vd, the period parameter P, and the priority parameter E may be provided.

With reference to FIG. 10, a scheduling process to be executed for CBR, VBR, or ABR when the setting request is received and when communication links are reset is described. In this case,

the scheduler 15 obtains a reference time (step S1001). The scheduler 15 then calculates a difference Vdd between the data amount parameter Vd provided as the communication parameter and the received data amount Vdr (step S1002).

If the difference Vdd is not more than 0 ($Vdd \geqq 0$), it is determined that the receiving side has completely received the data. Therefore, setting of a communication link for this transmission data is deleted from a schedule. If data transmission continues, however, this setting is not deleted from the schedule. In this case, the received data amount Vdr is initialized back to 0, and a new completion time Te is calculated by adding the period parameter S to the present time, thereby achieving continuous data transmission without resetting (steps S1011 to S1013). Nevertheless, the above setting may be once deleted from the schedule, and then a new setting may be made, taking the communication type as UBR with the sender address and destination address unchanged. In this case, the slave station 20 specified by the sender address can exclusively transmit Request_Packet from the new setting onward.

The scheduler 15 then calculates a difference Tb between the completion time Te of the transmission data and the obtained reference time (step S1004). If the difference Tb becomes not more than 0 ($Tb \leqq 0$), the scheduler 15 selects one or more transmission data predetermined in increasing order of the difference Tb as an object for communication link assignment

(resetting) (steps S1005 and S1008). Note that the reference time may be the transmission time of the assigned transmission band. On the other hand, if the difference Tb exceeds 0 ($Tb > 0$), the scheduler 15 multiplies the difference Tb by the effective transmission bandwidth Br to calculate a maximum transmission amount Vm ($= Tb \times Br$). The scheduler 15 further divides the difference Vdd by the maximum transmission amount Vm to calculate priority Rp ($= Vdd / Vm$) (step S1006). When the priority Rp is not less than a predetermined value, the scheduler 15 selects one or more transmission data predetermined in decreasing order of the priority Rp as an object for communication link assignment (resetting) (steps S1007, S1008). Thus, dynamic scheduling can be carried out by giving a high priority to transmission data which includes much data not transmitted with respect to the completion time Te.

After the above process has been repeatedly performed a predetermined number of times, communication link assignment (resetting) for the selected transmission data of CBR, VBR, or ABR is carried out (steps S1009, S1010).

Note that a random number Rn ($Rn = 0$ to 1) within a range of values that the priority Rp can take may be generated. Then, a comparison is made between the priority number Rp and the random number Rn, and transmission link assignment (resetting) may be carried out only for the transmission data whose priority Rp exceeds the random number Rn ($Rp > Rn$) (FIG. 11). With this

process, scheduling can be simplified.

Then, after assignment for transmission data of CBR, VBR, or ABR, transmission data of UBR is assigned to the transmission band that remains without an allocated communication link (FIG. 12).

With reference to FIG. 12, a scheduling process to be executed for UBR when the setting request is received and when communication links are reset is described. In this case, the scheduler 15 schedules the transmission data of UBR in sequence or based on the priority parameter E at the time of communication link setting. At this time, the transmission data with the higher priority parameter E is given a higher priority to be scheduled. Alternatively, the scheduler 15 calculates the difference Tb between the completion time Te of the transmission data and the reference time, and schedules the transmission data of UBR only if the difference Tb is not more than 0.

Note that, if the data amount parameter Vd is provided as the information for the transmission data of UBR, the scheduler 15 calculates the difference Vdd between the provided data amount parameter Vd and the received data amount Vdr. If the difference Vdd is not more than 0, it is determined that the data has been completely received by the receiving side. Therefore, setting of the communication link for this transmission data is deleted from the schedule.

Here, examples of methods for assigning (changing) the

transmission amount on each communication link at the time of scheduling are described below.

A first method is to assign the transmission amount by fixed length. In this first method, load on the scheduler 15 can be reduced. If the amount of data to be transmitted is small, however, the transmission band is wasted.

A second method is to change the assignment of the transmission amount so that packet lengths obtained by dividing the data amount parameter Vd become equal. In this case, upper and lower limits may be set for transmission amount assignment. In this second method, contrary to the first method, the transmission band is not wasted, but load on the scheduler 15 is increased.

A third method is to decrease the assignment of the transmission amount when more errors occur, and to increase when fewer errors occur, according to communication quality on the wireless channel. In this third method, the transmission band for use in re-transmission is reduced if the assignment of the transmission amount is small, while the transmission band equivalent to overhead for packet processing can be substantially reduced if large. However, if steep variation in error is observed and change of assignment of the transmission amount cannot follow the variation, the transmission band is wasted instead.

A fourth method is to increase assignment of the

transmission amount so that the same packet can be successively transmitted when the communication quality of a wireless channel is extremely low. The fourth method is extremely error proof, but the transmission band consumed is extremely large.

After the above-described scheduling, the master station 10 generates changed Map_Packet, and gives it to each slave station 20.

Note that the master station 10 determines that the transmission band is not in use when the assigned transmission band has not been accessed successively M times or for a time T passed, and reflects this determination result onto scheduling. Here, the number of times M and the time T may be fixed parameters or may be set for each communication link. However, for the transmission band for receiving Request_Packet (unused transmission band), assignment is not deleted even though the transmission band is not accessed. This is to ensure the transmission band for regularly receiving Request_Packet.

(4) Data transmission based on scheduling by the master station 10

Next, data transmission carried out by the slave station 20 that transmits Request_Packet and then receives scheduled Map_Packet from the master station 10 is described.

When receiving Map_Packet from the master station 10, the slave station 20 checks to see if any transmission band can be assigned to the requested data. This check can be done with the

communication link number and sender address in each band information portion of Map_Packet. For example, assignment can be done when the communication link number in the band information of Map_Packet coincides with the communication link number of the transmitted Request_Packet, or when the address of the slave station 20 is stored in the sender address. If the transmission band is assigned, the slave station 20 transmits the transmission data to a receiving side. For this transmission, a data packet (Data_Packet) shown in FIG. 13 is used. As shown in FIG. 13, Data_Packet is composed of a header portion, a data portion, and an ender portion.

The header portion is composed of transmission time stamp, sender address, destination address, packet type, sequence number, communication link number, packet number, the number of divisions, data length, and division number. In the transmission time stamp, based on the time counter of the slave station 20, a time when Data_Packet is transmitted, that is, a transmission time of the assigned transmission band is stored. In the sender address, the address of the slave station 20 that transmits Data_Packet (hereinafter, transmitting station) is stored. In the destination address, the address of the slave station 20 or the master station 10 that will receive the transmission data (hereinafter, receiving station) is stored. In the packet type, information indicating that this packet is Data_Packet is stored. In the sequence number, a serial number provided to each

Data_Packet is stored. In the communication link number, a communication link number of the assigned transmission band is stored. In the packet number, a serial number of an input packet provided by the terminal is stored. In the number of divisions, the number in which the input packet is divided for transmission as Data_Packet is stored. In the data length, the length of the data portion is stored. In the division number, a serial number provided to each segment packet obtained by division is stored.

In the data portion, the entire or part of the transmission data is stored based on the transmission amount of the assigned transmission band.

The ender portion is composed of information for use in well-known packet error detection.

The transmitting station uses the assigned transmission band to generate the above Data_Packet for each segment packet based on the specified transmission amount. The transmitting station then sequentially transmits Data_Packet in specified transmission timing (at transmission time), thereby transmitting the requested data to the receiving station.

Note that, when the slave station 20 is the receiving station, that is, when the address of the slave station 20 is the destination address in the band information portion of Map_Packet, the slave station 20 may intermittently receives the transmission data in accordance with a receive timing thereof or that of the following Map_Packet. Here, in intermittent receiving, main

components for carrying out wireless processing, control processing, and other processing are made to operate only when receiving a packet, thereby achieving reduction in power consumption. However, when not receiving Map_Packet correctly, the slave station 20 does not perform intermittent receiving until it can receive a next-coming Map_Packet correctly.

(5) Acknowledgement to the received transmission data

Next, transmission of an acknowledgement concerning a state of data transmission to the slave station 20 as the transmitting station and the master station 10 carried out by the receiving station (the slave station 20 or the master station 10) that has received Data_Packet is described.

When receiving Data_Packet from the transmitting station, the receiving station gives a state of data transmission (receiving state) in predetermined timing to the slave station 20 as the transmitting station and the master station 10. If the transmitting station is the master station 10, the receiving state is given only to the master station 10. To give the receiving state, an acknowledge packet (hereinafter, Ack_Packet) shown in FIG. 14 is used. As shown in FIG. 14, Ack_Packet is composed of transmission time stamp, sender address, destination address, packet type, sequence number, communication link number, receive history, and error detection.

In the transmission time stamp, a time when Ack_Packet was transmitted is stored based on the time counter of the receiving

station. In the sender address, the address of the receiving station, which sends Ack_Packet, is stored. In the destination address, the addresses of the transmitting station and the master station 10 are stored. In the packet type, information indicating that this packet is Ack_Packet is stored. In the sequence number, the transmission sequence number provided to the latest Data_Packet that was normally received is stored as it is. In the communication link number, the communication link number of the received Data_Packet is stored as it is. In the receive history, information indicating Data_Packet normally received before the sequence number is stored. For example, if the receive history is represented by 32 bits when the sequence number is "50", each of 32 bits of the previous sequence numbers 49 to 18 is stored with "1" assigned when Data_Packet was normally received, and "0" when otherwise. In the error detection, information for use in well-known packet error detection is stored.

The receiving station then transmits the above Ack_Packet to the slave station 20 as the transmitting station and the master station 10 in predetermined timing which will be described below.

At scheduling, the master station 10 assigns in advance unused transmission band for Ack_Packet transmission. Therefore, the receiving station can transmit Ack_Packet in transmission timing of the assigned transmission band.

On the other hand, when any transmission band cannot be assigned for Ack_Packet transmission in the above-described

manner, the transmission band used for Data_Packet transmission is also used for Ack_Packet transmission. For example, when Data_Packet is transmitted from the transmitting station to the receiving station i times (ten times, for example), Ack_Packet is transmitted from the receiving station to the transmitting station next one time. In this case, which station can use the transmission band is instructed with Map_Packet from the master station 10. Note that the number of times i may be set for each communication link (transmission band). Moreover, based on the communication quality of the wireless channel, the number of times i is dynamically changed so as to be decreased when more errors are observed, and increased when fewer errors are observed.

(6) Operation of the transmitting station or the master station 10 that received Ack_Packet

Next, the operation of the transmitting station or the master station 10 that received Ack_Packet is described.

When receiving Ack_Packet, the slave station 20 as the transmitting station checks a sequence number R and receive history stored in Ack_Packet. First, the transmitting station determines whether a difference between a sequence number R' previously received and the sequence number R currently received (R - R') exceeds the capacity of the receive history (the number of information stored in the receive history). If exceeds, the transmitting station sets the sequence number to be stored back to (R' + 1) for Data_Packet re-transmission. Such cases occur

when an error in receiving Ack_Packet successively occurs at the transmitting station, for example, meaning that a state of receiving Data_Packet between the sequence numbers R′ and R at the receiving station is unknown. For this reason, the transmitting station carries out re-transmission starting from Data_Packet coming next to the already-received one with the sequence number R′. On the other hand, if the difference does not exceed the capacity of the receive history, the transmitting station checks the receive history. Here, Data_Packet that corresponds to the sequence number whose bit of the receive history indicates "0" means that the receiving station has not yet received this Data_Packet. Therefore, the transmitting station first carries out re-transmission of Data_Packet starting from the one with the oldest sequence number. Then, after all Data_Packet required to be re-transmitted have been completely re-transmitted, normal transmission starts again from Data_Packet with the sequence number R before re-transmission.

With the above process, when fewer receiving errors are found, only Data_Packet with error is re-transmitted. When more receiving errors are found, that is, when the number of erroneous packets exceeds the capacity of the receive history, re-transmission is started from the first erroneous Data_Packet. Thus, efficient error re-transmission control can be performed.

On the other hand, when the master station 10 receives Ack_Packet, the controller 12 of the master station 10 checks the

sequence number R and receive history stored in Ack_Packet. The controller 12 then calculates the amount of data normally received by the receiving station also in consideration of variation in data amount due to re-transmission, and gives the calculated data amount to the scheduler 15. The scheduler 15 updates the given data amount as the received data amount Vdr. Thus, a state of data receiving can be reflected on the next scheduling.

As stated above, in the wireless communications system according to the embodiment of the present embodiment, the scheduling result of the scheduler 15, that is, the result of transmission band assignment, is regularly given to each slave station 20 by the master station 10 with the band assignment packet, and also recognized by the master station 10. Data transmission is carried out between stations with transmission band assigned thereto. Thus, any requested data of CBR, VBR, ABR, or UBR can be transmitted between stations.

The operations carried out by the master station 10 and the slave station 20 are shown in FIGS. 15 to 18 when each becomes the transmitting station and the receiving station. FIG. 15 is a flow chart showing the operation by the master station 10 as the transmitting station. FIG. 16 is a flow chart showing the operation by the master station 10 as the receiving station. FIG. 17 is a flow chart showing the operation by the slave station 20 as the transmitting station. FIG. 18 is a flow chart showing the operation by the slave station 20 as the receiving station.

(Specific examples of data communications)

Next, the operation of the wireless communications system according to the above embodiment of the present invention is specifically described exemplarily using a specific structure and data.

In a first example, as shown in FIG. 19, the master station 10, a slave station 21 to which a Set-Top Box (STB) 31 is connected, and a slave station 22 to which a digital television 32 is connected form the system, wherein image data is transmitted from the STB 31 to the digital television 32. Assume that the interface of the slave station 21 is an IEEE 1394 interface, and the slave station 21 is a cycle master having a timing control function of IEEE 1394. Also assume that the slave station 21 generates timing at IEEE 1394 side based on a time counter of its own for transmitting a cycle start packet (transmitted in a cycle of 125 μs).

When the slave station 21 is provided with data 100 by the STB 31, the controller of the slave station 21 determines whether a new communication link is required. If required, the slave station 21 calculates communication parameters required for the communication link. The communication parameters are determined by inquiring of the STB 31 and a resource manager (not shown) whether the data 100 is isochronous data or asynchronous one.

For example, if the data 100 is asynchronous control data, its transmission speed and data period are both variable.

Therefore, the communication type of the data is determined as UBR. If the data 100 is isochronous video data, the transmission speed and data period are calculated by accessing the resource manager of the IEEE 1394 network and the STB 31 for determining all communication parameters. If the transmission speed and data period are both constant, for example, 6Mbps and 33ms, respectively, the communication type of the data is determined as CBR. Similarly, if the transmission speed is variable but the data period is constant, 50ms, for example, the communication type of the data is determined as VBR. Also, if the average transmission speed is 2Mps but the data period is variable, the communication type of the data is determined as ABR.

In this example, image data is sent from the STB 31 to the digital television 32. Therefore, communication is made from the slave station 21 to the slave station 22. Thus, the slave station 21 generates Request_Packet 101 in which the address of the slave station 21 is stored as the sender address, the address of the slave station 22 is stored as the destination address, and the parameters determined in the above-described manner are stored in the communication parameter. The slave station 21 then transmits the generated Request_Packet 101 to the master station 10 in transmission timing of one unused transmission band based on Map_Packet 102 provided by the master station 10. On receiving Request_Packet 101, the master station 10 carries out scheduling for setting a new communication link, and then transmits

Map_Packet 103 to give information about assigned transmission bands to the slave station 21. The slave station 21 receives Map_Packet 103 from the master station 10, generates Data_Packet 104 based on the specified transmission timing and transmission amount, and then transmits the generated Data_Packet 104 to the slave station 22.

On receiving Data_Packet 104 from the slave station 21, the slave station 22 carries out error check of Data_Packet 104 and also manages the transmission sequence number and packet division information. Here, if the image data is divided into a plurality of Data_Packet, the slave station 22 buffers them to reconstruct the image data based on the packet division information. This reconstruction goes as follows. First, data of the same packet number is collected to construct the original data based on the division number and data length. Then, if the number of segment packets becomes equal to the number of divisions, data reconstruction is completed. The slave station 22 then outputs image data 107 reconstructed in the above described manner to the digital television 32.

On the other hand, when receiving Map_Packet 105 from the master station 10 and detecting that one transmission band has been assigned for Ack_Packet transmission, the slave station 22 transmits Ack_Packet 106 to the slave station 21 and the master station 10.

Next, when receiving Ack_Packet 106 from the slave station

22, the slave station 21 checks the receive sequence number and receive history included in Ack_Packet 106 and, if required, re-transmits relevant Data_Packet. Also when receiving Ack_Packet 106 from the slave station 22, the master station 10 checks the receive sequence number and receive history included in Ack_Packet 106, and reflects the check results on the next scheduling.

By repeatedly carrying out the above process, image data can be transmitted between the slave stations 21 and 22.

In a second example, as shown in FIG. 20, a master station 10 connected to a backbone network 40 in household, and a slave station 23 to which a personal computer (PC) 33 is connected form a system, wherein an Internet protocol (IP) data is transmitted from the PC 33 to the backbone network 40.

First, a flow of IP data is described. If the MAC address (address of an Ethernet interface) of a receiving device is not known, a transmitting device has to obtain the MAC address by using an address request protocol (ARP). A request packet for ARP (hereinafter, ARP request packet) includes the IP address and MAC address of the transmitting device and the IP address of the receiving device. The transmitting device transmits the ARP request packet to a broadcast address indicating the addresses of all devices. On receiving the ARP request packet, each receiving device gives its own MAC address to the transmitting device by using an ARP reply packet. Thereafter, the transmitting

device specifies one receiving device by using a set of the obtained MAC address and the IP address, and transmits an IP data packet to the receiving device.

To send the IP data to the receiving device over the backbone network 40, the PC 33 first outputs an ARP request packet 200 to the slave station 23. On receiving the ARP request packet 200 from the PC 33, the slave station 23 determines whether a new communication link is required. If a new communication link is required, the slave station 23 calculates communication parameters required for the new communication link for generating Request_Packet 201 in which UBR is set as the communication type because the ARP is used, the slave station 23 as the sender address, the broadcast address as the destination address. If the ARP is not used and the IP data is of IP version 4 (IPv4), the communication type is set as UBR. If the IP data is of IP version 6 (IPv6), the communication type, the transmission speed, and the data period are set according to the analysis results of the IP header and a real time protocol (RTP). Alternatively, the slave station 23 inquires of an application of the PC 33, and therefore the communication parameter is determined.

The slave station 23 then transmits the generated Request_Packet 201 to the master station 10 in the transmission timing of one unused transmission band based on Map_Packet 202 provided by the master station 10. On receiving Request_Packet 201, the master station 10 carries out scheduling to set the

requested communication link, and transmits Map_Packet 203 to give information about assigned transmission bands to the slave station 23. On receiving Map_Packet 203 from the master station 10, the slave station 23 generates Data_Packet 204 including an ARP request packet 205 in accordance with the specified transmission timing and transmission amount, and transmits the generated Data_Packet 204 having a broadcast address to the master station 10.

On receiving Data_Packet 204 from the slave station 23, the master station 10 carries out error check on Data_Packet 204, and also takes out the ARP request packet 205 for output to the backbone network 40. The master station 10 also passes the data to an upper-layer protocol. In the upper-layer protocol, a relation table is made to relate the sender address and IP address together.

When the receiving device over the backbone network 40 returns an ARP reply packet 206, the master station 10 passes the data to the upper-layer protocol. If, in the upper-layer protocol, the destination address (in this case, the slave station 23) is found by searching the relation table with the IP address as an argument, the master station 10 carries out scheduling to set a new communication link with the master station 10 as the sender address, the slave station 23 as the destination address, and UBR as the communication type. The master station 10 then transmits Map_Packet 207 to give information about assigned transmission bands to the slave station 23, and also transmits Data_Packet 208

including an ARP reply packet 209 to the slave station 23.

On receiving Data_Packet 208 from the master station 10, the slave station 23 takes out an ARP reply packet 209 for output to the PC 33. The slave station 23 also passes the data to the upper-layer protocol, wherein a relation table is made to relate the sender address and IP address together.

The PC 33 obtains the MAC address by receiving the ARP replay packet 209, and generates an IP data packet 210 for output to the slave station 23.

On receiving the IP data packet 210 from the PC 33, the slave station 23 passes the data to the upper-layer protocol. If, in the upper-layer protocol, the destination address (in this case, the master station 10) is found by searching the relation table with the IP address as an argument, the slave station 23 then determines whether a new communication link is required. In this case, it is determined that a new communication link is required. Therefore, the slave station 23 calculates communication parameters required for the new communication link, and generates Request_Packet 211 wherein UBR is set as the communication type because the IP data is of IPv4, the slave station 23 as the sender address, and the master station 10 as the destination address. The slave station 23 then transmits the generated Request_Packet 211 in the transmission timing of one unused transmission band based on Map_Packet 212 provided by the master station 10. At this time, if the transmission band has been already assigned for

the communication link by Request_Packet 201, the slave station 23 may transmit Request_Packet 211 using this assigned transmission band.

On receiving Request_Packet 211, the master station 10 carries out scheduling to set the requested new communication link, and transmits Map_Packet 213 to give information about assigned transmission bands to the slave station 23. On receiving Map_Packet 213 from the master station 10, the slave station 23 generates Data_Packet 214 including an IP data packet 215 in accordance with the specified transmission timing and transmission amount for output to the master station 10. At this time, if Map_Packet 213 includes an assigned transmission band for any other communication link of the slave station 23 without transmission data, the slave station 23 may transmit Data_Packet 214 using this transmission band.

On receiving Data_Packet 214 from the slave station 23, the master station 10 takes out an IP data packet 215 for output to the backbone network 40. At the same time, the master station 10 calculates the amount of data correctly received in consideration of variation in data amount due to re-transmission, and carries out scheduling by taking the calculated data amount as the received data amount Vdr (updating of scheduling). Thus, the state of data receiving is reflected on the next scheduling. Also, when detecting that one transmission band is assigned for Ack_Packet transmission as a result of scheduling, the master

station 10 transmits Ack_Packet 216 to the slave station 23.

On receiving Ack_Packet 216 from the master station 10, the slave station 23 then checks the receive sequence number and receive history included in Ack_Packet 216 to determine whether Data_Packet has to be re-transmitted.

By repeatedly carrying out the above process, IP data can be transmitted between the slave station 23 and the master station 10.

While the invention has been described in detail, the foregoing description is in all aspects illustrative and not restrictive. It is understood that numerous other modifications and variations can be devised without departing from the scope of the invention.